

- 1 -

"SYSTEM FOR THERMALLY INSULATING TUBULAR BODIES"

The present invention relates to a system for thermally insulating tubular bodies, such as for example pipes for transporting cold or hot fluids.

5 Many kinds of thermally insulating systems are known. In particular it is known that in order to form the lagging of a body of any shape it is possible to provide such a body with a double outer wall, in the interspace of which a material having low thermal conductivity, such as mineral wool, glass wool or polyurethane, can be placed.

10 However, the insulating properties of such materials are not very high, and in some cases it is necessary to use great thicknesses thereof for maintaining constant the internal temperature of the body. This is for instance the case of undersea pipes for transporting crude oil, that are generally formed by two coaxial tubes of carbon steel or stainless steel in which the oil flows in inner tube, while
15 the outer one acts as a protection; this construction is known in the field as "pipe-in-pipe". In order to allow long-distance piping of oil while avoiding that its viscosity increases, it must be maintained at the lifting temperature comprised between about 25 and 90 °C, and therefore in the interspace between the two tubes a great amount of insulating material is to be inserted. This requires the use
20 of an outer big-sized tube, and consequently the overall volume and weight of the pipe increase notably, since the amount of steel required for the outer tube rises quickly as a function of the diameter thereof. Also the costs for producing the pipe increase proportionally.

Alternatively, the interspace between the coaxial tubes may be evacuated so
25 as to exploit the low thermal conductivity of vacuum with a view to achieve the insulation of the pipe. In this case however the construction process of the pipe becomes more complex, and it is necessary that in the same interspace is placed a getter material able to absorb the gases that during time may outgas from the steel forming both tubes.

30 There are further well known evacuated insulating panels formed by a envelope wherein a filling material under vacuum is present. The envelope serves

to prevent (or reduce to the highest degree) the entrance of atmospheric gases into the panel, so as to maintain a vacuum level that is compatible with the thermal insulation degree required by the application. To this end, the envelope is made of so-called "barrier" sheets, that are flexible sheets characterized by a low gas permeability. Barrier sheets can be formed of a single component, generally polymeric, such as polyolefin or polyester (e.g., polyethylene terephthalate, PET). More commonly, however, barrier sheets are multilayers of different components. In the case of multilayers, the "barrier" effect is given by one of the component layers (this may be a polymeric layer, an aluminum foil, or a metallized plastic layer), whereas the other layers have generally the function of mechanically supporting and protecting the barrier layer. Multilayer barrier sheets are described, e.g. in US pat. nos. 4,594,279, 5,142,842, 5,236,758, and 5,943,876. The filling material on the contrary has mainly the function of maintaining the opposed faces of the envelope spaced out when a vacuum is made in the panel, and must have a porous or uneven internal structure so that the porosities or spaces thereof may be evacuated to perform the insulating function. This material can be inorganic, such as for example silica powder, glass fibers, aerogels, diatomaceous earth, etc.; or polymeric, such as polyurethane or polystyrene rigid foams, both in the form of boards and powders.

Thanks to their very low thermal conductivity, relatively thin evacuated panels are adequate to carry out an effective insulation of oil ducts. Therefore it is possible to reduce the internal dimensions of interspace of such ducts, thus reducing the entity of the above named problems.

For example, the publication PCT No. WO 01/38779 describes an evacuated insulating panel having tubular shape and suitable to be placed within the interspace of an undersea conduit for oil piping.

However, a first inconvenience of such panels is the brittleness of their envelope that can easily crack and may thus allow the passage of gases into the panel. Such a passage obviously jeopardizes the insulating properties of the panel and, in the case of undersea pipelines, it causes an irreparable damage because the replacement of the damaged panel cannot be effected.

Another drawback of evacuated panels lies in that they do not provide an adequate insulation to tubular bodies. As a matter of fact, they have generally a plane shape and must therefore be bent up to set side by side two opposed edges, in order to fit them to the tubular form of the inner interspace of oil ducts.

5 However, an evacuated panel curved in this manner does not allow to perfectly insulate the inner tube of the pipe, and in particular the zone corresponding to the edges that are set aside may become poorly insulated. In that zone in particular it can occur a cooling of inner tube and consequently also the oil flowing in inner tube get cold, thus thickening and causing a partial obstruction
10 in the pipe.

US Pat. No. 6,110,310 describes a system for the thermal insulation of pipe-in-pipe conduits, formed of at least two layers of superimposed curved insulating panels; the joints of the panels are preferably staggered, so that there is almost no part of the inner pipe that "sees" the outer pipe, resulting in a further reduction in
15 heat loss. However, the panels of US 6,110,310 contain as filled a molded element made of microporous materials. The microporous materials comprise a mixture of inorganic oxides and preferably also inorganic fibers, to increase the mechanical stability of the molded element. The molded elements of this patent require rather deep incisions in order to be bent, making their construction rather complex.
20 Besides, inorganic filler materials are rather heavy.

The object of the present invention is therefore to provide an insulating system for tubular bodies, which is free of such inconveniences.

Said object is achieved by means of an insulating system comprising at least two superimposed evacuated panels, each of which is internally evacuated and is
25 essentially formed by an envelope inside which there is contained a discontinuous or porous filling material, each panel being rolled up on itself to the extent that its two opposed edges which are parallel to the rolling axis are set aside and its other two edges perpendicular to the rolling axis form the end edges of the rolled evacuated panel, characterized in that at least one of said evacuated panels
30 comprises a polymeric filling material and at least another evacuated panel comprises an inorganic filling material.

Advantages and features of the insulating system according to the present invention will be evident to those skilled in the art upon reading the following detailed description of an embodiment thereof with reference to the attached drawings, in which:

5 - Figure 1 shows a cross-sectional view of a double-walled duct, in the interspace of which the insulating system according to said embodiment of the invention is inserted; and

 - Figure 2 shows a longitudinal section view of the duct in Fig. 1.

 With reference to figures 1 and 2, there is shown a section of a pipe wherein
10 the insulating system according to the present invention is installed. The pipe is formed in a known manner by an inner tube 1 and an outer tube 2, being coaxial with inner tube 1 and having such a diameter that between said tubes an interspace 3 is present. Inside tube 1 the fluid to be insulated, for example oil, is let to flow. The tubes 1 and 2 can be made of any suitable material, for example carbon steel
15 in the case of undersea pipes for transporting oil.

 In interspace 3 two evacuated panels 4 and 4' are disposed, each of which is rolled up so as to set side by side its two opposed edges 5 and 5' that are parallel to the rolling axis. The other two edges, that are perpendicular with respect to the rolling axis, form thus the end edges 6 and 6' of the rolled panels 4 and 4'. In such
20 a manner, the evacuated panels 4 and 4' take a tubular arrangement and fit with the tubular form of the interspace. In case, said opposed edges 5 and 5' may be mutually sealed by any known means, for instance by hot sealing.

 The two so rolled panels 4 and 4' become reciprocally inserted and are preferably disposed in interspace 3 in such a way that the edges 5 of panel 4 are
25 staggered with respect to edges 5' of panel 4', and are preferably arranged in a position diametrically opposed with respect to said edges 5', as shown in figure 1. Similarly, also the end edges 6 of rolled panel 4 are staggered with respect to end edges 6' of rolled panel 4', as it appears from figure 2.

 This construction, in which the edges of the panels are both diametrically
30 and longitudinally staggered, is preferred because it allows to obtain a substantially even thermal insulation by almost completely eliminating the heat

passage that could occur through the poorly insulating zone at the edges of a panel; in particular, this construction practically eliminates the heat conduction between pipes 1 and 2 due to the radiation contribution, and also minimizes the contribution to heat loss due to convection of gases present in interspace 3.

5 The insulating system according to the present invention comprises at least two evacuated panels, with at least one of the evacuated panels of the insulating system comprising as a filling material a polymeric material, whereas at least another panel uses an inorganic filling material that may be in form of powders, fibers or mixtures thereof.

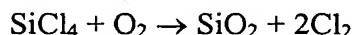
10 The evacuated panel with polymeric filling material may contain said material both in the form of powders or in the form of a porous one-piece board. Preferred polymeric materials are polystyrene and, particularly, polyurethane; particularly preferred are panels containing a board of open-cells polyurethane. In these panels the thermal conductivity rises rather quickly with pressure, from
15 about 10 mW/m·K when the internal pressure is about 1 mbar, up to about 35 mW/m·K at atmospheric pressure. For this reason, the envelope of polymer-filled panel of the system of the invention is preferably made of a barrier sheet, generally of the multilayer type; preferred multilayer sheets are those comprising a metal foil (preferably aluminum) surrounded by plastic layers for mechanical
20 support, as widely known in the field. The polymer-filled panel may also contain a getter material or device, to get rid of the traces of gases that may penetrate into the panel over its working life. Panels of this kind are described for instance in US Pat. No. 5,843,353.

25 The evacuated panel with inorganic filling material may contain powders, fibers or mixtures thereof.

 In the case of fiber-filled panels, the fibers may be mineral or glass fibers, e.g. rock-wool and preferably glass-wool. Glass fibers suitable for use in the present invention are commercially available, and are sold for instance from the US company ISORCA Inc., of Granville, OH, under the trade name Isomat.

30 A preferred form of inorganic filling materials are powders of an inert material having preferably a mean particle size of less than 100 nanometers (nm)

and preferably comprised between about 2 and 20 nm. Particularly preferred is the use of silica. Silica having the desired dimensional characteristics can be obtained by precipitation from alkali solutions of silicates; this kind of silica is produced and sold for instance by the UK company Microtherm International Ltd., under the names Microtherm G, Microtherm Super G or Waterproof Microtherm Super G. Alternatively, it is possible to use pyrogenic silica, a form of silica obtained by burning in a special chamber SiCl_4 with oxygen, according to the reaction:



The silica produced in this reaction is in the form of particles having dimensions comprised between few nanometers and some tens of nanometers, which can be possibly bound to form particles having larger dimensions. Pyrogenic silica is produced and sold for example by the US company CABOT Corp. under the name Nanogel[®] or by the German company Wacker GmbH.

Compared with polymer-filled panels, those based on inorganic powders undergo less changes in thermal insulating characteristics in case of cracks. As a matter of fact, the thermal conductivity of these panels changes only slightly upon entrance of air, thus remaining below about 8 mW/m·K for internal pressures up to some tens of mbars, and reaching a maximum value of about 20 mW/m·K at atmospheric pressure. As a consequence, the production of these panels has less stringent requirements as to the material used for the envelope, that in this case may be a simple plastic sheet.

It is also possible to use mixed kinds of inorganic fillers. For instance, it is possible to have a panel mainly containing powders, to which mineral fibers (e.g. glass fibers) are added, so as to obtain a mixed body that can be easily consolidated and produced in the form of blocks with a thickness of even few millimeters; these blocks can be enveloped, evacuated and subsequently rolled with relative ease. Other inorganic additives may be added, such as opacifiers to reduce the radiant heat transport in the panel, as described in US Pat. 6,110,310.

Panels with inorganic filling withstand high temperatures better than the ones comprising polymeric filling materials and can thus be used as a protection of these latter, by placing them in interspace 3 in contact with the hotter between

pipes 1 and 2. Therefore, in the case of ducts for piping oil, these panels are favorably arranged directly in contact with the inner tube 1 so as to protect the panel comprising the polymeric filling material from possible damages due to a protracted exposure to the high temperatures of crude oil flowing in inner tube 1.

5 In the case of figure 1, panel 4 comprises preferably an inorganic filling material, while panel 4' is based on a polymeric filling material.

Of course, the insulating system of the invention may comprise more than two panels, for instance three or four, compatibly with cost, weight and overall thickness constraints imposed by the application.

10 Even though the present invention relates to the insulation of a conduit for piping oil, the insulating system according to the present invention can be used to insulate any other body having tubular shape, for example a boiler or a pipe for transporting a cryogenic fluid such as liquid nitrogen or oxygen.

The system of the invention has the advantage that it obtains very good
15 thermal insulation properties, but with an overall lower weight and lower costs compared with systems using only panels containing microporous inorganic materials.